INFLUENCE OF TOPSOIL QUALITY PARAMETERS ON CROP YIELD

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INTRODUCTION

Soil quality, climatic and topographic conditions and management practices are key factors dictating soil productivity. In western Canada it is well recognized that past and current tillage practices have caused soil degradation such as organic matter (OM) loss, increased salinization, and increased erosion. Often the phrase - reduced soil quality - is used. But what constitutes a quality soil? Factors that contribute to soil quality and the subsequent effect on crop production have not been well defined or quantified, largely due to the confounding effects of climate. Soil conservation practices are being promoted in order to improve soil quality. It is essential that we understand what factors contribute to soil quality in order to implement more effective agronomic practices.

In order to avoid the confounding effects of climate and subsoil variability, a unique field study has been initiated at Lethbridge where several different topsoils were relocated to the same site. Our objective is to isolate soil factors and relate these factors to crop production.

MATERIALS AND METHODS

Site Locations

Two sites were established at the Agriculture Canada Research Station, Lethbridge, Alberta. One site is under dryland management while the other is under irrigation. The original soil at both sites was a Dark Brown Chernozemic. The sites were selected for a uniform Ah horizon depth (18-20 cm). Both sites had been under a cereal/fallow rotation for several years.

Site Preparation

Sites were established in 1990. The original topsoil (Ap/Ah horizon) was mechanically removed with a hydraulic excavator. The excavator was very effective with no disruption or compaction of the subsoil. The surface of the exposed subsoil was lightly tilled to create a rough interface with the deposited topsoils. Thirty-six soils (34 topsoils, 2 subsoils), each replicated 3 times, were deposited at each site in a randomized block design. The soils were relocated by truck to the sites and deposited into 5m X 6m plots. Depth of the re-deposited soil was about 15 to 18 cm. Each plot required about 7 tonne of soil (one truck load). Prior to seeding, the plots were split into two subplots: with (60 and 100 kg N/ha for dryland and irrigation respectively) and without N-fertilizer. The soils were selected on the basis of organic matter content, texture, and cropping history (Table 1). About half the soils were collected from existing experiments at the Lethbridge Research Station including long term rotations, irrigation experiments, and manure application studies. Two soils were originally subsoils (B and C horizon) under native grassland. The remaining topsoils were donated by producers within 100 km of the sites. These latter soils varied greatly in soil characteristics and came from several agroclimatic areas.

Table 1. Range values of selected characteristics of the relocated topsoils.

Soil parameter	Dryland	Irrigation
Organic C (%)	0.63 - 7.48	1.04 - 5.54
Inorganic C (%)	0.009 - 2.50	0.002 - 2.25
Total N (%)	0.052 - 0.637	0.102 - 0.616
pH	5.26 - 7.38	5.64 - 7.46
Extractable NH_4-N (μg N/g)	0.22 - 24.5	1.15 - 12.2
Extractable NO_3-N (μg N/g)	2.13 - 242	0.97 - 137
Extractable PO_4-P (μg P/g)	1.23 - 507	3.68 - 726
Sand (%)	9.0 - 81	12 - 86
Silt (%)	3.7 - 48	2.7 - 45
Clay (%)	15 - 54	12 - 53

Soil Analysis

After the topsoils were in place, bulk soil samples were collected from each plot. The samples were air-dried and ground through a 2 mm sieve. The topsoils were analyzed for pH (1:5 soil to 0.01M $CaCl_2$ ratio w/v), total C and N (Carlo Erba NA 1500 N/C/S Analyzer), inorganic carbon (acid digest, gas chromatography), extractable nitrogen (2M KCl extractable, Technicon AutoAnalyzer II), PO_4-P (0.5M $NaHCO_3$ extractable, ascorbic acid colorimetric determination), and texture (pipette method).

Crop and Harvest

Both sites were seeded (67 and 100 kg/ha dryland and irrigation respectively) to hard red spring wheat (*Triticum aestivum* var. Lancer) in 1991. Phosphorus fertilizer was placed with the seed (40 kg P_2O_5/ha). All of the above-ground material was hand harvested from 5 rows each 5 m long within each subplot. The plant material was threshed and the grain, straw, and total dry matter yields were determined. The irrigation site received 12.7 cm of irrigation water in June and July.

Statistical Analysis

Statistics was performed using the Statistical Analysis System (SAS Institute Inc. Cary, North Carolina, USA).

RESULTS AND DISCUSSION

The monthly rainfall pattern at the dryland site was above normal during the growing season as compared to the 30 year monthly averages. June was particularly wet with a total rainfall 70% above the 30 year average. The crop was not subjected to serious drought stress.

Due to wild oat and root rot infestations, yield data from 5 dryland soils and 2 irrigation soils were not included in the analysis.

There was no response to nitrogen fertilizer at the dryland site (Table 2). As a result the check and fertilized subplots yields data were averaged for each plot. The most likely explanation for the lack of nitrogen fertilizer response is that the experiment was established on land that was under fallow in 1989 and the relocated topsoils were kept under fallow during 1990 after they were deposited at the site. The extended fallow period would have allowed for the accumulation of plant available nitrogen through net mineralization.

The opposite was true for the irrigation site. The crop did respond to nitrogen fertilizer and there was a significant soil x nitrogen fertilizer interaction (Table 2). The irrigation site was established on stubble and no summerfallow period was allowed. The available nitrogen level was most likely low and the additional water used for more biomass production resulted in the observed response to nitrogen fertilizer.

The effect of soil type on total dry matter and grain yields was highly significant (Table 2). The range of yields at the dryland site varied by a factor of 3 (Table 3). At the irrigation site there was a 3-fold difference between the minimum and maximum yields from the unfertilized subplots. The range in yields for the N fertilized subplots varied by only 2-fold. However, the maximum yields for the unfertilized

Table 2. Summary of analysis of variance to determine the effects of soil, nitrogen fertilizer and their interaction on grain and total dry matter (TDM) yields. Five soils from the dryland site and two soils from the irrigation site were not included in the analysis because of weed and disease infestations.

	Dryland (31 soils)		Irrigation (34 soils)	
Source	Grain	TDM	Grain	TDM
Soil (S)	***[1]	***	***	***
N fertilizer (F)	ns	ns	*	***
SxF	ns	ns	**	*
Block	*	ns	***	***
CV (%)	9	9	13	12

1 ns = not significant; *, **, *** indicates significance at P=0.05, 0.01, and 0.001 respectively.

Table 3. Total dry matter (TDM) and grain yield ranges. Yields from five dryland soils and from two irrigation soils are not included because of weed and disease infestations.

	Dryland		Irrigation			
			-N		+N	
	Min	Max	Min	Max	Min	Max
TDM (tonne/ha)	2.6	9.4	2.7	10.1	5.2	10.9
Gain (tonne/ha)	1.2	4.0	1.2	3.7	2.1	3.9

and fertilized subplots were similar (Table 3). At the irrigation site the lower yielding soils responded to N fertilizer whereas the higher yielding soils did not respond to N fertilizer. The lowest yielding soils at both sites were the two subsoils.

Yields from the dryland site were positively correlated with organic C, total N, and extractable NO_3-N and PO_4-P and negatively correlated with inorganic C and pH (Table 4). Similar relationships occurred at the irrigation site except for grain yields from the N fertilized subplots. Grain yields from the irrigated, N fertilized subplots essentially did not correlate with selected soil properties except for inorganic C. Lodging was a serious problem with certain soils and this could have affected the final grain yield.

Table 4. Correlation coefficients for the linear relationship between selected soil properties and total dry matter and grain yields. Five soils from the dryland site and two soils from the irrigation site were not included in the analysis because of weed and disease infestations.

Soil parameter	Dryland	Irrigation	
		-N	+N
Total Dry Matter			
Organic C	0.39	0.40	0.34
Total N	0.43	0.42	0.33
Extractable NO_3-N	0.63	0.45	0.27
Extractable PO_4-P	0.49	0.24	ns
Inorganic CO_3-C	-0.58	-0.56	-0.44
pH	-0.40	-0.31	-0.28
Sand	ns[1]	-0.27	-0.21
Silt	ns	0.37	0.25
Clay	ns	ns	ns
Grain			
Organic C	0.27	0.31	ns
Total N	0.31	0.31	ns
Extractable NO_3-N	0.52	0.32	ns
Extractable PO_4-P	0.34	ns	ns
Inorganic CO_3-C	-0.57	-0.54	-0.20
pH	-0.32	ns	ns
Sand	ns	ns	ns
Silt	ns	0.24	ns
Clay	ns	ns	ns

[1] ns = not significant.

Scatter plots of yield against soil organic C and total N clearly show two components in yield variation (Figure 1). Yield increased up to a certain content of soil organic C and total N beyond which the yield essentially levelled off. The two phase response can effectively be described by a linear plateau model fitted by non-linear regression. This linear plateau model accounted for a higher proportion of variability (Figure 1) then observed with a linear model. The linear plateau model suggests that about 2% organic soil carbon is the optimum content for crop production. Such a general preliminary statement can only apply to the prairie region of SW Alberta under which conditions the experiment was conducted. For soils with less than 2% organic C content, there was a wide range of yields among soils with similar organic C content. This suggests that soil organic matter quality or other soil characteristics can affect productivity as much as the quantity of organic matter.

CONCLUSIONS

These preliminary (first year) results clearly demonstrate the usefulness of the field technique of relocating different soils to one location. By keeping the climatic, topographic, subsoil, and management factors constant it was possible to show the wide range in productivity of different soils reflecting the range of soil quality. Even when water and nutrients (N and P) were not limited a 2-fold difference was observed between the lowest and highest yielding soils.

Not only is soil organic matter quantity important but also organic matter quality. Future work will attempt to identify and quantify the parameters that are important to soil organic matter quality. Emphasis will be placed on soil biochemistry and microbiology factors.

A supplementary long time objective of this study will be to determine how the relocated soils will change with time, particularly those from different climatic environments. This aspect will be important regarding the effect of global climatic change on soil properties and hence soil productivity.

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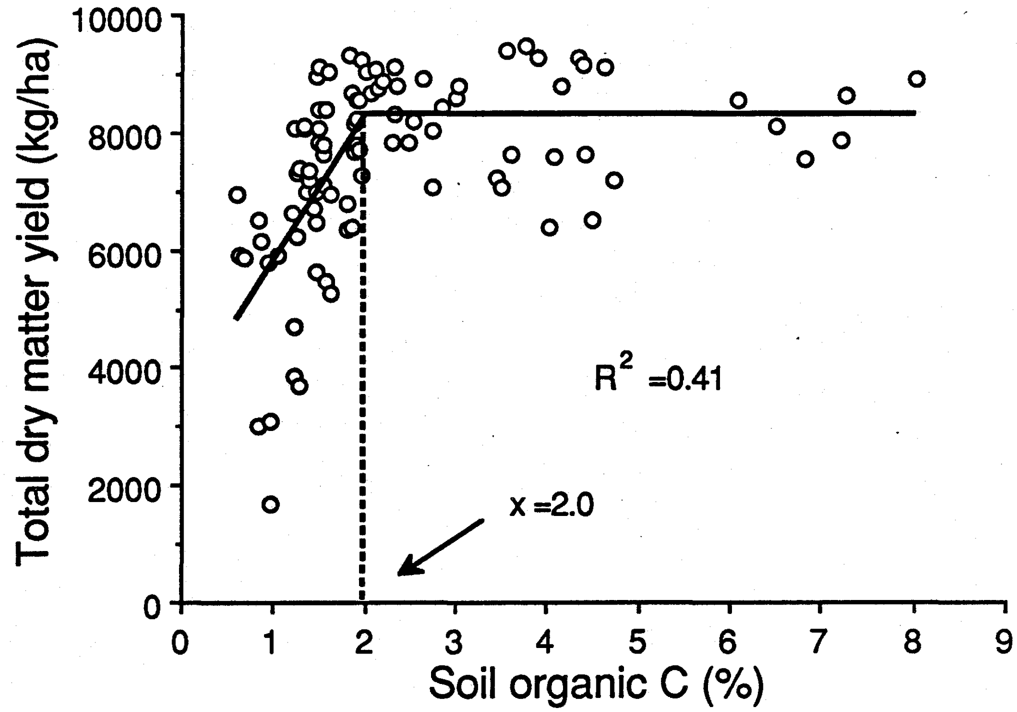

Figure 1. Relationship between total dry matter yield and soil organic C or total N at the dryland site as determined by non-linear regression.